Exploring future cost supply curves of biomass using data of IMAGE 2.1 and two different production functions.

Monique Hoogwijk[1*, a], Detlef van Vuuren[a], Bert de Vries[a]
[a]National Institute of public health and the environment (RIVM), Bureau for Environmental Assessment, Antonie van Leeuwenhoeklaan 9, P.O.Box 1, 3720 BA Bilthoven, The Netherlands, telefax: +31 30 2744435, email: Monique.Hoogwijk@rivm.nl

Background and objective

Many studies in the past assessed the future global potential of energy crops. However, most studies did not include the possible competition with food and fodder neither the cost aspects of biomass energy. In this study we try to include these aspects using the Integrated Assessment Model IMAGE 2.1. We simulate the future cost supply curves of energy crops at a 17-region level in two steps:

1. We study the site potential[2] of energy crops taking the possible competition with land for food into account.
2. We use a Cobb-Douglass production functions to construct the dynamic cost supply curves of energy crops.

The Integrated Assessment Model IMAGE 2.1

The IMAGE 2.1 model (Alcamo, R.Leemans et al. 1998) is developed to study the impacts of climate change and is divided in three sub-models: The Energy-Industry System (EIS), The Terrestrial Environment System (TES) and the Atmospheric Ocean System (AOS). Within TES, first the demand for food and materials is calculated at a 17-region level. These amounts of biomass are allocated over the world using grid cells of 0.5° x 0.5°[3]. TES can also allocate land for biomass using a demand from the EIS. Therefore IMAGE 2.1 is a useful tool to assess the site potential of energy crops taking the future demand for food into account.

Approach

The site potential is assessed, using a scenario run in which we set the biomass for energy purposes at zero. We use the SRES A1b and B1 scenario (IPCC 2000). Classifying the yield in 25 classes we assess the amount of biomass that can be produced at the area not used for food and fodder (agricultural area). We also excluded various forest types.
We use furthermore a Cobb-Douglass production function for the cost calculations. Using the Cobb-Douglass production function we simulate the substitution from a labor-intensive production system to a more capital based production system with raising wages.

The Cobb-Douglass production function can be written in the form (Equation 1):

$$Y = Y_0 * \left(\frac{K}{K_0}\right)^{\alpha} \left(\frac{L}{L_0}\right)^{1-\alpha} \qquad \text{Equation 1}$$

Y = output
K = capital stock

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[1] Also Utrecht University, Department of Science, Technology and Society, Utrecht, The Netherlands
[2] We defined "site potential" as the highest amount of primary biomass for energy purposes that can be obtained without influencing the normal land use functions
[3] At equator 50 km x 50 km

L = labor input
α = Cobb-Douglass coefficient

We assume that the actual factor inputs K and L tend towards their optimal values, which therefore results in a substitution of labor-intensive to capital-intensive production system.

The costs of biomass are calculated using Equation 2.

$$ct = \frac{[aK_t + bY_t / Yld_t + wL_{req,t}]]}{Y_t} \qquad \text{Equation 2}$$

a = annuity factor
b = fixed cost price of land
w = wages

Furthermore we modele the increasing yield due to technology development using both the concept of learning-by-doing modeled by an experience curve as well as a fixed increase in the management factor, the way it is currently modeled in IMAGE 2.1

Results and conclusions

At the moment only preliminarily results can be presented, since extra effort should be put in finding input parameters per region. Only test runs with IMAGE 2.1 are done and an example cost calculation has been done. These show that the region Latin America have the highest site potential. This is consistent with other studies on the biomass potential assessment (Williams 1995),(Dessus, Devin et al. 1992), (Johansson, Kelly et al. 1993), (Fischer and Schrattenholzer 2000).

Furthermore it showed that the Cobb-Douglass production function is a useful tool to simulate the substitution from labor to capital.

References:

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